



Potato Production in Ontario

 Ministry of
Agriculture
and Food
ONTARIO
Jack Riddell, Minister
Clay Switzer, Deputy

PESTICIDE WARNING

Many chemicals are very poisonous to man and livestock as well as to insects, disease organisms and weeds. Some are very dangerous to the operator at the time of application. Most dangerous residues on the crop disappear in a short time, while some have a long residual effect. Do not apply any materials in excess of the recommended amounts as it is possible to have a residue on the potatoes at harvest.

For the safe handling of these products, carefully follow all warnings and directions which are found on every carton and container. Pay particular attention to suggestions about working in crops following treatments.

Aerial applicators must be licensed by the Ontario Ministry of the Environment to apply pesticides. In addition, permits are required from the Ontario Ministry of the Environment under the authority of The Pesticides Act 1973 for the application of Schedule 1 and 5 pesticides, and Schedule 2 hormone-type herbicides. The area will be inspected by Ministry personnel to ensure safety of application.

It is an offense under the Federal Pest Control Product Act to use a control product under unsafe conditions. Precautionary practices must be heeded at all times to prevent drift. Extra precautions should be taken when using insecticides applied by air, especially those known to be toxic to honeybees, e.g. Sevin (carbaryl).

Applications should not be made if the wind is blowing. Some drift occurs even on the stillest day. To keep drift to a minimum, apply pesticides in the evening or early morning.

Be sure that the product to be used and its rate of application are specified in the contract.

POTATO PRODUCTION IN ONTARIO

This publication was revised by the following members of the Ontario Regional Potato Committee:

ONTARIO AGRICULTURAL COLLEGE, UNIVERSITY OF GUELPH

R.G. Rowberry (retired), Department of Horticultural Science

E.C. Lougheed, Department of Horticultural Science

R.H. Coffin, Agriculture Canada, Department of Horticultural Science

ONTARIO MINISTRY OF AGRICULTURE AND FOOD

M. Valk, Muck Research Station, Bradford

S. Squire, Provincial Potato Specialist, Alliston

A.W. McKeown, Horticultural Experiment Station, Simcoe

ONTARIO POTATO GROWER'S MARKETING BOARD

W.L. Armstrong, Secretary-Manager

CONTENTS

Economic Importance	3
Climatic Requirements	3
Soil Requirements and Management	3
Planting and Cultivation	7
Cultivars (Varieties)	12
Potato Production on Organic Soils	12
Irrigation	13
Diseases	14
Insects	33
Leaf-feeding Insects	33
Other Insects	37
Harvesting	40
Storage	41
Marketing	47
Utilization	48
Quality	48
Production Costs	51
Regulations Respecting Table-stock Producers	51
Seed Production	52
Selected Publications	55
Conversion Tables	56

ECONOMIC IMPORTANCE

Potatoes are a major farm crop in Ontario. Maincrop and seed potatoes are grown mainly in the central and eastern parts of the province and, to a lesser extent, in the north; early potatoes are most important in the southwestern region.

Some 16,000 hectares are planted annually, 600 of which are for the production of certified seed. Total production is approximately 34,000 tonnes, enough to supply about half the population of Ontario; however, one-third of this production is processed into chips (75%), dehydrated (10%) or pre-peeled products (7%), French fries (5%) and in soups and stews (3%). The shortage of French fries is made up by shipments from New Brunswick and Manitoba; that of early table-stock potatoes mainly from the southeastern states, while the Maritime provinces make up the shortage in the main crop.

Open-market prices for table-stock may vary widely from year to year, influenced somewhat by North American production and demand as a whole, but particularly by the southeastern states and Quebec for the early crop and the Maritime provinces for the maincrop. Over the past decade gross annual returns to the growers have varied from \$23 to \$57 million.

CLIMATIC REQUIREMENTS

Present commercial cultivars are derived from species originating in the mountainous regions of Chile in South America, at latitudes from 30° to 45°S. The growing season at these high altitudes is characterized by moderate temperatures and long days, conditions which are found in the potato-growing districts of Ontario.

A mean daily temperature of 18 to 21°C during July is considered best for highest yields, together with a rainfall of 25 mm per week throughout the growing season.

Lack of adequate moisture in July and early August is usually the most serious limiting factor in potato production in Ontario.

SOIL REQUIREMENTS AND MANAGEMENT

The ideal potato soil is usually described as "a deep, friable, well-drained, sandy loam, free from stones, moderately acid (pH 5.5 to 6.0), and containing adequate organic matter". Such a soil warms up quickly in the spring, holds water well and provides good aeration for development of tubers. It responds to fertilizer and can be highly productive.

This does not mean that other soils are not suited for potato production, but the use of soils which are too coarse or too fine in texture will lead to difficulties during

some years. Very coarse soils dry out too much in dry years, delaying germination, reducing yield and stunting top growth. Because of this reduced top growth, any weeds present have less competition, and soil temperatures may increase sufficiently to produce potatoes that darken after cooking. Fine-textured soils tend to remain cold and wet in the spring, causing seed pieces to rot in the ground. Compaction later in the season often causes misshapen tubers and difficulties at harvesttime.

Most Ontario potatoes are grown in the coarser-textured soils which, when well managed, produce high yields. These soils are well suited to mechanized potato production.

Crop rotation and manures

The type of rotation practised is important in soil management. Specialist growers tend to grow potatoes year after year in the same ground, but this practice may result in reduced yields and the buildup of disease organisms. A long rotation, e.g. potatoes once in five or six years with hay or cereal crops, is excellent for maintaining good soil structure, but does not fit in with the type of farming they wish to practise.

Potatoes every third year, with cereal and forage crops, is a desirable compromise, but a forage crop which is to be plowed immediately before the potatoes are planted should consist mainly of legumes rather than grass. Legumes in the rotation reduce *Verticillium* wilt besides adding nitrogen to the soil when plowed. Grass roots are often infested with wireworms and white grubs (June beetle larvae) which attack the potato tubers.

If the soil is too acid for good legume growth, but otherwise suitable for potatoes, dolomitic limestone should be applied before establishing the legume(s). The amount should be determined by a soil test to avoid the creation of conditions favorable for the rapid growth of any scab organisms present.

Barnyard manure, like green manure, is very good for improving soil structure and increasing the aeration and water-holding capacity. Well-decomposed barnyard manure may be applied to sod or a green-manure crop in late winter or early spring before seedbed preparation. However, if the manure contains large amounts of undecomposed straw or shavings, it should not be applied in the spring because this undecomposed material will contribute to a rapid buildup of scab organisms. This type of manure should only be applied early the previous fall and incorporated into the soil.

If a sod or grain crop precedes the potato crop and the soil is plowed in the late summer, a cover crop of winter rye or oats should be sown in the latter part of August or early September to control erosion during the fall and winter. If the cover crop is following well-fertilized potatoes, the residual fertilizer probably will

be sufficient for the cover crop. The oat cover crop will winter-kill and may be incorporated into the soil during the preparation of the seedbed. Potatoes following an oat cover crop have been found to have a higher specific gravity than those following rye. The rye cover crop should be incorporated into the soil by disking or plowing as soon as soil conditions permit. However, rye grows very rapidly in a wet spring and it may be difficult to work the large amount of green tops into the soil, thereby making poor planting conditions. Potatoes should not be planted less than 10 to 14 days after plowing down a heavy crop of rye in the spring, because the breakdown products of the rye may damage or even kill the seed.

Nutrient requirements

The potato crop has large nutrient requirements. Under favorable soil and weather conditions, high yields can be produced and therefore the crop can use liberal quantities of barnyard manure and commercial fertilizer. Ten tonnes of tubers, plus the vines and roots, contain approximately 70 kg of nitrogen, 20 kg of phosphorus (as P_2O_5) and 95 kg of potassium. Much larger amounts than these must be available in the soil, or become available during the growing season, because plant roots are not 100% efficient in extracting available nutrients from the soil. Soil analysis is intended to determine the amount of nutrients necessary to supplement those supplied by the soil for good growth.

Proper nutrient balance is also important. If one plant nutrient is out of balance with the others by being either deficient or in excess, the yield and quality of the crop can be depressed. For example, if full response to added phosphorus and potassium is to be obtained, the plant must have access to an adequate and continuing supply of nitrogen. Moreover, potassium should not be present in excess of that needed for best growth; it is so readily absorbed by plants that luxury absorption may occur and depress the uptake of other essential elements, resulting in reduced yield and dry-matter content. Furthermore, a deficiency in one nutrient may be accentuated by adding other nutrients. Magnesium is becoming deficient in many potato-growing areas of Ontario. It is now a routine check in soil tests, and recommendations are made when deficiencies occur.

The potato crop requires smaller amounts of calcium and sulfur, and minute quantities of trace elements such as copper, boron, and zinc. These elements are seldom deficient and should be applied only when a need is known to exist, in accordance with specific recommendations.

Potato quality as related to fertilizer

Differences in cooking quality occur in Ontario each year. Experimental evidence indicates that most of this variability is due to differences in soil type, climate, and cultivar of potatoes. Dry-matter content is reduced as the rate of fertilizer application is increased. Potassium in the muriate form will cause more

reduction than potassium in the sulfate form. Applying all or part of the potash in the previous fall has no effect on yield or quality. While reduction in dry matter does not affect the cooking quality of table stock, it may be an important consideration when potatoes are to be sold for processing. If higher specific gravity is desired, two practices will be helpful:

- apply fertilizer at rates no greater than those indicated by a soil test;
- substitute sulfate of potash for part or all of the muriate normally applied at planting time.

Fertilizer recommendations

Soil tests should be made to ensure adequate and properly balanced fertilization for the highest yield and quality of the crop.

Representative soil samples should be taken, preferably in the fall, and sent to a soil-testing laboratory for analysis and fertilizer recommendations. It is the responsibility of the grower to supply accurate and detailed information so that a valid recommendation can be made.

It is recommended that fertilizer be applied at planting time in bands at least 2.5 cm below and at least 6 cm to each side of the seed piece. This is especially effective in soils of low fertility, but in soils of high fertility broadcasting the fertilizer gives very little yield reduction compared to banding. Broadcasting also speeds up the planting operation and reduces rusting in potato planters.

Liquid fertilizer of similar analysis and amount applied to the soil is as effective as dry fertilizer.

Urea and diammonium phosphate have been found to be as satisfactory as ammonium nitrate and triple superphosphate as sources of nitrogen and phosphorus respectively.

There is no evidence that it is profitable to supply extra nutrients under normal conditions, either by side-dressing or by foliar application, when the fertilizer requirements of the crop have been adequately met at planting time. However, in a very wet year, potatoes grown on a sandy soil may benefit from a side-dressing of nitrogen, applied when the plants are about 20 cm high, to replace nitrogen which has leached out of the soil.

Foliar fertilization

The application of liquid fertilizers to the foliage is an impractical method of supplying the N, P, and K requirements of potatoes, and is not recommended.

PLANTING AND CULTIVATION

Selection of seed

No grower now plants seed without knowing the cultivar, but far too many still plant seed without knowing how much disease it is carrying.

Foundation seed grown from Elite stock costs more than uncertified, but the extra cost is small and is greatly exceeded by the returns from increased yields that may be expected from the use of high-quality seed relatively free from virus diseases.

Most of the seed planted in Canada is "A" size (115 to 340 g), which is cut into several pieces. This is an economical use of seed but is probably responsible for the spread of bacterial ring rot on this continent. The use of whole "B" size seed (40 to 115 g) avoids the use of the cutting knife, but this seed must have a Foundation or Certified rating. Small seed from this source has been either close-planted to give this size of seed or graded out from regular sizes. Small seed from uncertified stock is often small because the parent plants were diseased and stunted.

All seed should be passed over a grader, and rotten or diseased tubers discarded before planting.

High-quality, small, whole seed has several advantages over cut seed.

- (1) It is much more tolerant to extremes of temperature and moisture in the soil at planting time and almost always gives a perfect stand, especially if it has been green-sprouted.
- (2) It is more resistant to attack by soil-borne diseases and insects.
- (3) If the seed crop was vine-killed before the arrival of the green peach aphid, the seed will be free from virus leaf roll, assuming that the mother-tubers were free from infection.
- (4) Cup-type planters can be used instead of pick-type, thereby reducing the spread of any disease which may be present.
- (5) If the seed is of the proper size, no cutting is necessary.

If cut seed is to be used, each seed piece should be blocky in shape, contain at least two eyes, and weigh 40 to 60 g. Seed may be cut immediately before planting, or cut and stored after curing for up to three weeks. In either case the cutting knife should be disinfected.

Chemical seed treatment to control seed-borne diseases such as *Rhizoctonia* and scab is not considered practical. The use of resistant cultivars and cultural practices

which tend to suppress the organisms are the most practical controls. However, treatment of the seed for Fusarium wilt is important in preventing the contamination of new land or land not seriously infested. Details of seed treatment are given in OMAF Publication 363, *Ontario Vegetable Production Recommendations*.

Seed-piece decay is caused by: (1) diseased seed; (2) poorly stored seed; (3) planting in soil which remains below 7°C for a long time; and (4) planting cold seed in hot soil. Visibly diseased tubers should be sorted out of the seedlot prior to cutting. Curing the cut seed increases resistance to decay and improves plant stands. A thin, corky layer is formed on the cut surfaces preventing the entry of decay-causing organisms.

Healing (curing) is promoted by: (1) high humidity; (2) plenty of oxygen (air); (3) no direct sunlight; and (4) temperatures of approximately 15°C. For best results all of these conditions need to be met. Cut seed being held before planting should be treated at the end of the cutting line with a talc, fungicide-type seed treatment. This helps dry up cell ooze and keep the cut pieces from sticking together. The cut, treated seed should cure well in 7 to 10 days. Store in slatted pallet boxes or in bulk (not more than 1.3 metres deep) over the slotted air vents on the storage-bin floor. Sufficient humid air flow around the cut seed is essential to prevent heating and/or decay.

An alternative method is "green-sprouting". This is as beneficial to whole "B" size seed as to cut seed. Seed pieces are exposed to light for one to three weeks, during which time cut surfaces heal. Short, thick, green sprouts develop which are very resistant to attacks by Rhizoctonia, and an even stand of vigorous plants is obtained very soon after planting.

Soil preparation

The soil should be loose, well drained and friable to a depth of at least 30 cm. The seedbed should be uniformly tilled to a depth of at least 20 cm. Good drainage and aeration are essential for the development of well-shaped, high-quality tubers.

Date of planting

The best date of planting for any region depends on the length of the growing season and the time of year when the crop can be marketed to best advantage. In the north, full maturity of late cultivars may be limited by late summer frosts. In general, yield and quality of potatoes are improved by early planting, but planting early in cold, poorly prepared soils delays the emergence of plants and often results in a poor stand. Approximate dates of planting and frost-free periods for the different climatic zones of the province are given in OMAF Publication 363, *Vegetable Production Recommendations*, but the real criterion is that the soil should be at least 8°C at planting depth first thing in the morning.

Depth of planting

The depth at which potato seed pieces are planted varies with the type of equipment or method used and with the soil texture. Seven to 10 cm is generally satisfactory. Planting too deeply may retard emergence or reduce the plant stand, but deeper planting is advisable in droughty soils, especially if temperatures are above normal.

Plant and row spacing

Within limits, the yield of a potato crop is not affected by plant spacing. Individual plants compensate for wider spacings by producing more tubers or by increasing tuber size. Thus, for any particular field, the best spacing is the one which gives the highest yield of tubers in the desired size range.

With ample soil moisture and high fertility, spacing exceeding 30 cm is not desirable for most cultivars. Plant spacings of 20 to 25 cm are the most common, with 90 cm between rows, although some growers prefer rows as close as 75 cm.

One notable exception to this is the cultivar Russet Burbank, which produces a smooth, long, medium-sized tuber desirable for baking. To obtain this, there must be a perfect plant stand, with a plant spacing of 30 to 40 cm, and an even moisture supply throughout the growing season. "A" size seed must be cut carefully to ensure that each seed piece will germinate; hence whole "B" size seed is preferable. The seed must then be precision-planted because misses in the row cause oversize, misshapen, unmarketable tubers on adjacent plants.

Planting

Most planters are of the two-row type, but there is an increasing number of four-row machines and even a few six-row on the larger farms. The pick-type of planting mechanism is now the most common, but the cup-feed is becoming popular in some of the newer machines. The advantage of the cup-feed is that seed-pieces are not pierced, so the spread of disease is reduced. The tuber-unit planter takes whole tubers from the hopper, cuts them and plants the pieces consecutively. This is of special use to seed growers as it enables them to plant much larger acreages in tuber-units. However, unless the seed tubers are completely disease-free, the combination of the picks and the cutting knives gives a double opportunity for the spread of any disease which may be present in any tuber. Thus for Elite-grade seed, the preferred method of planting would be to plant sized, whole seed with a cup-type planter.

Cultivation

Cultivation should be mainly for the control of weeds. Under some conditions it may be necessary to increase aeration of the water-absorbing capacity of the soil

surface. Two or three cultivations and one hilling are commonly carried out. A preemergence cultivation to control weeds is best done with a spike-tooth harrow or finger-weeder.

When plants have emerged, row cultivation is the usual practice, using various types of attachments. Shallow cultivation, in which weeds are cut off or buried, causes least root-pruning and is preferable to deep cultivation. No further cultivation should be done after plants begin to bloom.

Hilling

Hilling is carried out as a final cultivation to smother small weeds in the row and to provide a suitable volume of well-aerated soil in which the tubers can grow and be protected from greening (sunburn) and frost.

Research in New Brunswick and Ontario shows that hilling is not necessary for early potatoes. Immediate leveling of the hill left by the planter gives earlier emergence and the potatoes reach a marketable yield sooner. This does not apply to maincrop potatoes; the total yield is the same but there is more greening and the danger of blighted and frozen tubers.

Hilling of maincrop potatoes can be carried out at the stage of crop growth which best suits the grower. As noted, where a herbicide is not used, hilling can be the final operation in a series of cultivations. If a preemergence herbicide is used, hilling must be completed before the herbicide is applied, otherwise the effect of the herbicide will be destroyed and fresh weed seeds brought to the surface.

The recommended method is to keep the crop clean by light cultivation until it is about 10 cm high, then cover with 1 to 2 cm of soil in the shape of the final hill required. The herbicide may then be applied. Some growers now set their planters' covering disks to leave the final hill and apply the herbicide directly to this hill. Emergence may be delayed slightly, but the time and cost of several operations are saved.

On coarse-textured soils a broad type of hill with a saucer-shaped depression is recommended, to increase the absorption of rainfall and reduce the danger of soil being washed from around the tubers. The mold-board and disk types of hiller are the most satisfactory because they cause least damage to the potato root system.

Chemical weed control

Weeds are an important factor in reducing yield of potatoes. Most farmers realize that a heavy growth of weeds means lower crop yields, but few realize that a light weed growth, especially early in the season, can be responsible for reduced yields.

Control of weeds is important in reducing disease. Some weeds are attacked by the same disease organisms that affect potatoes. If the weed cover is reduced or eliminated, there is less chance of disease spreading to the potato plants.

Weeds also harbor insects which can move to the potatoes. These insects not only cause damage when feeding on the crop plants, but can transfer disease organisms also from weed hosts to healthy crop plants.

A heavy growth of weeds interferes with spray coverage and with drying after rain and dew, making conditions favorable for early and late blight infection.

Weeds with a matted root system or many rhizomes (underground stems, as in twitch grass) may interfere with vine separation on the harvester and many marketable tubers may ride over the back and be lost.

Cultivation is still an important method of weed control. The use of chemicals combined with proven cultural practices now makes it possible to produce potatoes under almost weed-free conditions. Recommendations for the use of chemicals (herbicides) will be found in OMAF Publication 75, *Guide to Chemical Weed Control*. This publication is revised each year and is available from county agricultural offices; the Consumer Information Centre, Ontario Ministry of Agriculture and Food; or the Colleges of Agricultural Technology.

The use of herbicides should be related to the long-term use of each field and should not be considered as a replacement for proven cultural practices. No herbicide can be expected to kill all weeds and weed seeds.

Under most conditions in Ontario cultivation with a harrow or finger-weeder will be sufficient to control seedling annual weeds between planting and first hilling. If the weed cover is light, one hilling may be all that is necessary.

Preemergence herbicides may be used from soon after first hilling to emergence of the crop; under some conditions the field will be weed-free until harvest. Post-emergence treatments may be used after the crop is up to control weeds growing among the potato tops. This type of treatment requires higher pressure (345 to 415 kPa) than that commonly used in weed sprayers. If the field sprayer used for applying insecticides and fungicides is to be used for herbicides, modification should be made so that the pressure can be reduced to this range. Treatments should be made when weeds are small, using only enough pressure to ensure that the herbicide spray droplets reach the leaf surface of seedling weeds.

CULTIVARS (VARIETIES)

A wide range of cultivars is adapted to the different climatic zones and market requirements of the province. New cultivars are constantly being tested and suitable ones recommended for the various areas and conditions. Descriptions of these and recommendations for their use are to be found in Publication 363, *Ontario Vegetable Production Recommendations*, which is revised annually.

POTATO PRODUCTION ON ORGANIC SOILS

The commercial potato acreage on organic soils is quite small compared with potato production on mineral soils, chiefly because other crops are more profitable.

Soil

Organic soils are ideal growing media for potatoes because they are loose and open and allow for proper development of the tuber; generally they have a high water-holding capacity and are cool, properties which encourage high set of tubers and large yields. Good growers are able to obtain consistent yields of 38 t/ha.

Soils formed from the accumulation of partly decomposed plants such as water lilies, swamp grasses, sedges, and cattails are particularly suited for the development of clean, white tubers. Potatoes from woody peat and muck usually have a much darker skin color and skins are often stained. As they do not wash as well as those from grass peat, they are mostly brushed.

Soils which are neutral to alkaline in reaction should be avoided for potato cultivars susceptible to scab.

The soil should be well prepared, particularly newly broken grass peat. Raw peat is difficult to break up finely. Lumps 5 to 8 cm in diameter often occur, making the soil very loose and open so that light penetrates and discolors the skin.

On woody types of organic soil, large pieces of wood which might interfere with equipment should be removed. This is necessary almost every year because the woody material is continually being worked toward the surface by the action of frost and by tillage equipment.

The water table should be held at a constant level 75 to 90 cm below the soil surface. A fluctuating water table above this level is detrimental to root development.

In dry years irrigation has been shown to increase yields substantially and also to improve dry-matter content.

Depth of planting

The kind of muck, its physical condition, and weather conditions at planting time, all affect the depth at which the seed piece should be planted. Shallow planting in soils that tend to be wet results in better stands and higher yields. On fibrous, well-drained peat soils the planting depth is not as critical as on well-decomposed organic soils. The range in depth of planting potato seed pieces is 5 to 10 cm.

Plant and row spacing

The quick growth and high yield normally obtained on most organic soils result in the formation of many oversize tubers. To avoid this, closer planting than on mineral soils is recommended. The most satisfactory distance is 20 cm in the row and 80 to 85 cm between the rows.

Cultivation and weed control

Chain harrows or plank drags are effective in eliminating the early flush of weeds. Chain harrows, in particular, can be used even when potato sprouts are emerging from the soil. When plants are 20 to 25 cm high, and at least one cultivation has been done between rows, rows should be hilled to a height of about 10 cm; this will smother weeds that have germinated. The final hilling operation, at or near blossom time, is important. Because of the loose, open texture of the soil, the hills are often blown or washed down, and growing rhizomes and tubers break the soil. The hills at this time should be formed sufficiently wide and high to provide the best growing medium for the cultivar used.

Chemical weed control

Preemergence chemical weed control can be used on organic soils but the plants must be covered at the time of application. Some herbicides used on mineral soils are not recommended on organic soils because there is a risk of crop injury the next growing season from herbicide residues. Consult OMAF Publication 75, *Guide to Chemical Weed Control*.

IRRIGATION

In southern Ontario, a moisture deficit during the potato-growing season in most years is the most common single reason for low yields. Highest yields are obtained when rainfall is evenly distributed throughout the growing season at the rate of 25 mm per week. This ensures that water available for plant growth remains above 50% of the water-holding capacity of even the coarser-textured soils. Tuber development is retarded only when the available soil moisture falls below the 50%

level; thus, irrigation is needed only when the rainfall is less than 25 mm per week.

The major benefit from irrigation is increased yields. In addition, the increased growth of tops enables potato plants to compete successfully with weeds and prevents the soil temperature from becoming too high — an important factor in the prevention of after-cooking darkening.

Hot, dry weather followed by heavy rain is the main cause of rough, knobby tubers. Supplementary irrigation prevents the undesirable effects of dry spells.

Irrigation equipment is expensive, but growers with a moisture deficit of 8 cm or more every year should consider irrigation. Equipment costs vary according to sources of supply, distance from source, type of system, etc., but under most conditions operating and fixed costs are covered by an increase in yield of 2.8 t/ha. Prospective buyers would be wise to visit growers already using irrigation to see the different types of equipment and installations, and to discuss the merits of each. An Agricultural Engineer is available for advice in your area and may be contacted through your local agricultural office. See the section on irrigation in OMAF Publication 363, *Vegetable Production Recommendations*.

DISEASES

OMAF Publication 363, *Vegetable Production Recommendations*, contains the most recent recommendations and resistant cultivars.



Figure 1

Bacterial Ring Rot can be one of the most destructive diseases of potatoes in Ontario. It appears toward the end of the growing season and is first recognized by wilting and yellowing on the outer leaflets which later become mottled, then brown, and finally shriveled. One or more stems may be affected or the entire plant may become stunted and wilted.

The disease is caused by *Corynebacterium sepedonicum*. Bacteria enter tubers through the stem and often will cause the skin of seriously infected tubers to crack in a star-shaped fashion (Figure 1). If such tubers are cut across, yellow-brown areas, usually in the form of a ring, are seen in the vascular region (Figure 2). These areas develop into a creamy brown, cheesy, odorless rot which at times may be ropy. When secondary bacteria enter, a foul-smelling rot may occur and the tuber may be completely destroyed.



Figure 2

It is doubtful whether the disease bacteria are harbored in the soil but they are carried on infected tubers, the cutting knife, and in dried slime on crates, bins, sacks, machinery and other materials which have touched diseased potatoes. They gain entrance through wounds and invade the vascular system.

A very low level of undetected ring rot in a seed lot can quickly be increased to 20-30% by use of a mechanical seed-cutter and a pick-type planter.

Control

- (1) Use government-inspected and tagged seed.
- (2) Wash or steam very thoroughly, then sanitize all potato equipment, storages, and anything that touches the potatoes, both at the end and beginning of each season.

Sanitize with a quaternary ammonium compound at 500 parts per million unless otherwise directed on the label.

It is good practice to sanitize cutters, planters and seed-piece boxes between different lots of seed.

Note: The disinfectant should remain wet at least 30 minutes after application.

- (3) Avoid injuring potatoes at harvest. This can increase light infections to severe amounts.
- (4) If ring rot is suspected in a crop, have the tubers or plant stems tested at a laboratory such as the Diagnostic Centre at the University of Guelph. If the test is positive and you had planted tagged, government-inspected seed, notify either your local Agriculture Canada seed-potato certification officer or the Ontario Ministry of Agriculture and Food Specialist at the Alliston Agricultural Office for advice.
- (5) Try to establish which fields are infected and which are not. Disinfect the equipment and harvest the uninfected fields first. Dispose of potatoes from the infected fields for processing or the fresh market immediately. If this is not practical store them last, as they should come out first.
- (6) Dispose of all potatoes for table-stock or processing and do not use them for seed. Bury culls in non-cultivated land.
- (7) Thoroughly clean everything as outlined in (2) before bringing in new seed stocks.

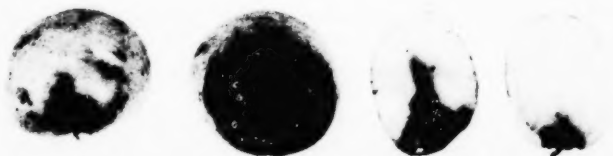


Figure 3



Figure 4



Figure 5

Blackleg is responsible for serious lesions through soft-rot breakdown. This is more likely to be severe in potatoes intended for chipping, which are held at a higher temperature than in potatoes for the fresh market or seed. The disease frequently reduces the stand of plants in the field. The causal organism is *Erwinia atroseptica*, a bacterium.

Blackleg may be recognized by a rolling of the edges of upper leaves accompanied by a gradual yellowing and, finally, a severe wilting of the whole plant (Figure 5). The base of the stem is black and this blackening may spread up the stem a considerable distance (Figure 4).

Infected tubers may rot completely in the soil, but more often there is only a black depression at the stem end. When such tubers are cut lengthwise, a V-shaped decayed area is seen (Figure 3). Affected tubers break down in storage and the rot spreads to other tubers, particularly if the humidity is high or if moisture condenses on them.

The blackleg disease does not have an offensive smell but soft-rot bacteria, which are usually present, impart a disagreeable odor.

The causal organism survives mainly in infected tubers and will infect fresh seed pieces. Seed-maggot flies may carry the organism from cull piles or from decaying tubers to cut seed before or after planting; upon hatching, the young maggots burrow into the seed piece, introducing blackleg bacteria to the interior of the tuber.

Control

1. Use Foundation seed and discard all tubers showing signs of decay.
2. Store Foundation seed potatoes separately in a clean, preferably disinfected, storage. Use a quaternary ammonium disinfectant.
3. Dump rubbish and culls from potato storage well away from any fields where potatoes will be grown. Covering the cull piles with earth-fill is helpful.
4. Avoid bruises and injuries at harvesttime. Tubers showing decay should be discarded at digging. To facilitate the "corking-off" of all wounds, the storage should be held at 15 to 18°C with a high relative humidity, for 10 to 14 days at the beginning of the storage period, before lowering it to storage temperature.

Verticillium Wilt has become a serious problem in the major potato-growing areas, partly due to the practice of very short rotations, or none at all, and the susceptibility of current cultivars to the disease. It is present in all potato-growing areas in Ontario and is becoming more serious each year, causing an estimated 10% overall loss in commercial acreages. It also affects tomato, pepper, eggplant, strawberry, blackberry, etc. Causal fungi are *Verticillium albo-atrum* and *V. dahliae*.

It is sometimes difficult to separate wilt from several other diseases with similar symptoms, e.g. blackleg and bacterial ring rot.

The symptoms are normally observed in the latter part of summer, particularly if the weather is very hot and dry; the progress of wilting is less obvious in cool weather. The lower leaves usually start to wilt first and wilt progresses up through the whole plant. The wilted leaves roll up, droop, turn yellow, shrivel and die.

If the infected stem is split lengthwise or cut across, a brown discoloration is noticed just beneath the surface in the "woody" tissue (vascular area) of the stem.

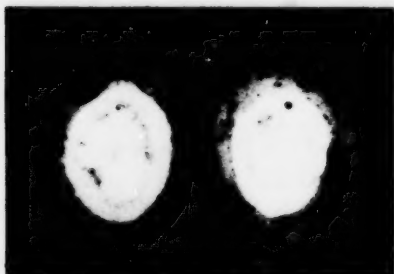


Figure 6



Figure 7

Not all stems from the same seed piece may show the disease. The tubers usually have an internal discoloration which shows as a brown ring when cut near the rhizome (stem) end (Figure 6).

In addition, under certain conditions not yet understood, the skin surrounding the eyes at the tuber may be colored pink or brown, called "pink-eye" or "brown-eye". These areas, which superficially resemble the damage caused by late blight, frequently break down with soft rot (Figure 7).

There are three methods by which *Verticillium* fungus can be spread: (1) the organism may be in the soil; (2) inside the seed; (3) on the surface of the seed or in the soil particles present in or on the container. These three points must be kept in mind in a control program.

Control

- (1) There is no good economic control available. The value of a rotation is dependent on the control of broad-leaved weeds. Unless there is 100% control of these weeds in the alternate crops, the wilt will not be reduced significantly.
- (2) Plant Certified potato seed from a crop free of wilt.

Common Scab is perhaps the most common and widespread disease of potatoes. It may be found also on the garden beet, sugar beet, turnip, parsnip, carrot and radish. It is recognized by slightly raised spots of rough, corky tissue, varying in size and shape. These spots may be few and scattered or may be so numerous that they involve the entire surface, causing disfigurement of the tuber. Depending on the nature of the scab, either shallow russetting or deep scab lesions may be found. With deep scab lesions, blackened, sunken cavities may be present. Scab does not penetrate deeply and, while most of the skin may be covered with scab, the flesh is not injured to an appreciable degree; however, it renders potatoes unsightly and unmarketable (Figure 8).

The causal organism of potato scab, *Streptomyces scabies*, lives in the soil and on infected tubers. It appears to be native to some soils. It may remain alive for many years after a crop of scabby potatoes has been grown. It occurs in nearly every potato-growing region. The scab organism develops most readily in muck and in dry alkaline soils rich in organic matter.

Control

Few methods control potato scab completely and a method found to be suitable in one type of soil is not necessarily effective in another. Several general control measures, however, help to reduce the amount of scab.

- (1) The best method is to plant a resistant cultivar.

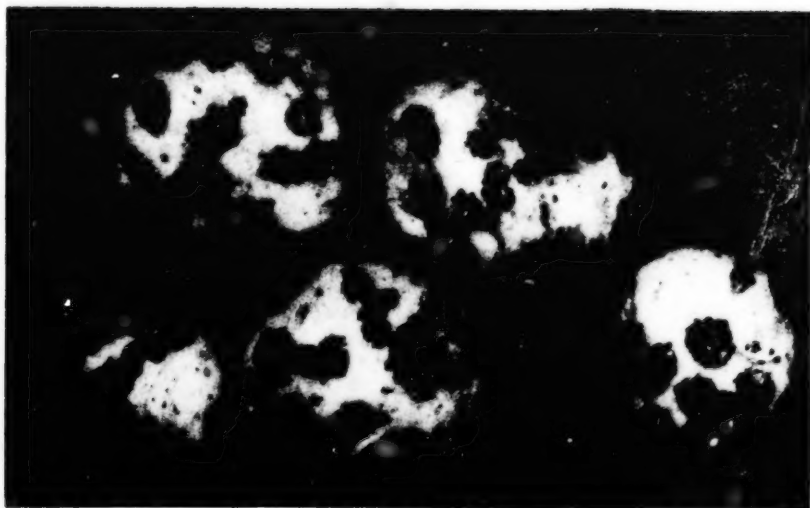


Figure 8

- (2) Only tubers free from scab should be used for seed.
- (3) Tubers should be planted in moderately acid soils (pH 5.5 to 6.0) unfavorable for the scab organism.
- (4) A crop rotation of three to four years or even longer is advisable. Only thoroughly rotted manure should be used where potatoes are grown. Green-manure crops (especially soybeans) plowed under help to reduce scab. Avoid the use of lime before planting potatoes.

Rhizoctonia is also known as black scurf, Rhizoctonia canker and aerial tuber. It affects many other crops including cabbage, beet, tomato, tobacco, sugar beet, etc. The disease is presently found in all potato-growing areas. The causal fungus is *Rhizoctonia solani*.

Rhizoctonia is more serious for Ontario potatoes than is generally realized. It often reduces the stand and retards growth by stem girdling, and the black scurf stage detracts from the appearance of the tuber, affecting marketability, especially of washed potatoes.

Symptoms on tubers consist of brown to black lumps (scurf) which do not wash

off on the surface of new tubers (Figure 9). Sometimes severe russetting is associated with this stage.

Symptoms on developing shoots and rhizomes consist of brown to black sunken cankers which may eventually girdle shoots and rhizomes (Figure 10). Often the young shoots are killed, resulting in misses in the row, or, if shoots eventually do emerge, in a very uneven stand of potatoes.

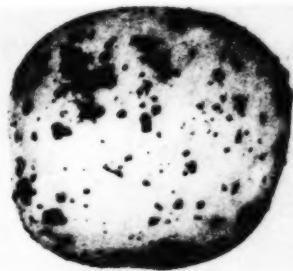


Figure 9

Aerial tubers: Cankers on the stems of older plants prevent food, which is produced in the leaves, from passing down into the young tubers. This stimulates the lower buds on the stem to enlarge and develop into aerial tubers (Figure 11). With cultivars such as Norland and Sebago, the upper leaflets turn purplish. This may be confused with purple-top, a disease caused by the aster-yellows mycoplasma.

The developing shoot may become infected by a fungus living from one year to the next in the soil, or from a fungus on the surface of the seed piece. Although most, if not all, potato soils in the province are infested to some extent with the



Figure 10



Figure 11



Figure 12

Rhizoctonia fungus, it is common to find areas in a field where infection of plants is much higher.

Control

- (1) Crop rotation using corn or grain, with an interval of three or four years between potato crops, will help, particularly in those fields where the disease is serious. If possible, avoid using crops mentioned as prone to Rhizoctonia in the rotation.
- (2) Shallow planting of seed pieces often reduces the amount of shoot damage, particularly if the weather turns wet and cold following planting.

Silver Scurf detracts from the appearance of washed potatoes in plastic bags. The disease may be hardly noticeable at digging time but will increase rapidly and spread in storage if the temperature is above 10°C and humidity is excessive.

Small, localized spots may be present or a considerable area of the tuber may be affected, especially on the stem-end half of the tuber. The affected areas have a silvery appearance, particularly when the tubers are wet. Later they turn brown and the tissue under the spot may shrivel (Figure 12).

The fungus that causes the disease, *Helminthosporium atrovirens*, is distributed on tubers and survives in the soil.

Control

- (1) Plant seed free from disease.
- (2) A long rotation may help in keeping silver scurf to a minimum.
- (3) Dig the crop as soon as it is mature.
- (4) Store seed tubers and table stock at the coolest suitable temperature and avoid excessive humidity.

Early Blight affects potatoes, tomatoes, peppers, eggplants and solanaceous weeds (relatives of potatoes). The causal fungus is *Alternaria solani*.

The disease is found in all parts of the province. Early blight rarely causes losses in potatoes where insects and late blight have been controlled because the current fungicides used for late blight also control early blight. However, it is almost always present in trace amounts and, depending on weather, can reduce yield by causing the leaves to wither.

Symptoms usually do not appear until the potatoes are either in bloom or have started to set tubers. The disease first occurs on leaflets as small, dark brown to black lesions which enlarge to produce target-like spots (Figure 13). These spots are often surrounded with a narrow, yellowish area which fades into the normal green of the leaf. The spots may be angular and are usually limited by the larger veins. The lowest leaves may be affected first and if the spots are numerous, these leaves will turn yellow and eventually dry up. This yellowing of the leaves progresses upward as the plant matures so that finally there may be only a terminal tuft of green leaves. Occasionally the stems and tubers are affected. The disease is particularly severe on weakened plants, especially those affected by virus.



Figure 13

The causal organism survives the winter and between crops on the remains of the old potato tops. The spores are wind-borne and generally, upon germination, penetrate the epidermis directly to establish the organism within the leaf. Some strains are wound parasites (i.e. they enter the leaf through the wounds), which

explains why there is frequently more early blight where flea beetles and leafhoppers are inadequately controlled.

Control

- (1) Crop rotation is important in helping to prevent early infection of the current crop. The greater the distance between the fields used last year and the present crop, the more effective is this control practice.
- (2) Spray program — see OMAF Publication 363, *Ontario Vegetable Production Recommendations*, for information on materials, rates and timing.

Late Blight usually is noticed first in the field about the beginning of August. Sometimes it may not be seen until digging time, when a few blighted plants or tubers may be found, or it may not be observed until the tubers have been in storage for several weeks. The disease is particularly serious in wet seasons, when losses may be heavy.

Purplish-brown areas appear on the skin of affected tubers, either in the field or in storage. A reddish-brown dry rot develops in the flesh under these areas. The diseased tissue dies and shrinks and irregular, slightly sunken spots develop on the tubers. The blighted tubers may be attacked by other organisms, causing a wet rot. This may occur in the field during wet weather or under warm, damp, storage conditions.

Dark brown to black dead areas appear on the leaves, often near the margin or tip of a leaflet. If a diseased leaf is held up against the light, a watersoaked margin may be seen about the dark area, or the dead area may be surrounded by a pale green zone. During wet weather, a sparse, whitish mold growth develops around the margins of the spots, more often on the underside of the diseased leaves. Often this can be seen in the morning while the leaves are still wet with dew. During warm, humid weather the brown area may enlarge very rapidly until the whole leaf is blighted. Elongated, dark brown spots or streaks appear on the stems of blighted plants.

Early blight, hopperburn and tipburn may be confused with late blight. Leaflets affected by hopperburn and tipburn become pale green or yellowish at the tips and along the margin. The edges later turn brown and roll up. Leaves affected by early blight develop angular to rounded dark brown spots, usually with concentric ridges.

Late blight is caused by a fungus, *Phytophthora infestans*, that lives over the winter in potato tubers. In the spring, the fungus in a diseased seed tuber grows up inside a shoot and produces spores on the mold growth that develops on the leaves and stem. These spores are splashed about by rain and blown by the wind to other potato plants, where they start new infections. Blighted potato plants frequently are

found growing on piles of refuse and culled potatoes dumped from a storage. These are sources of infection for nearby potato fields.

During rains, spores of the late-blight fungus are washed into the soil, where they may cause tuber infections. The deeper the covering of soil over the tubers, the less chance of infection occurring. Spores may be shaken off the tops on to the potatoes during digging. Rot resulting from this will be seen some weeks later in storage.

Control

- (1) Tubers that show signs of rot should not be used for seed.
- (2) The destruction of volunteer potato plants on cull piles is very important. If potato sprouts develop on refuse piles, destroy them immediately, using a top killer or a strong weed killer. Repeat the application if more sprouts appear.
- (3) A number of late blight-resistant cultivars have been developed and may be grown to advantage. Because they are not immune to all strains of the late-blight fungus, other control measures should not be neglected.
- (4) Spraying with a fungicide is an important measure for the control of late blight. The same program provides control of early blight. Start when the plants are 10 to 12 cm high. In southern Ontario, early-maturing cultivars may be dug before late-blight weather occurs, and sprays may be needed for insect control only.

It is usually sufficient to spray every 10 days. If the weather is wet, an application may be needed every five to eight days, or oftener, to keep the tops protected at all times. Continue spraying until the tops are killed by a top killer or by frost.

Even though a good spray schedule has been followed, late blight may be present at digging time. If the tops are killed, the fungus and the spores soon die and there will be little danger of inoculation and infection during harvest. Use a commercial top killer and apply it about two weeks before digging. This allows time for the fungus to die out completely. If the tops are killed by frost, a top killer is not needed to control late blight.

Powdery Scab has been reported from northern Ontario, but it has never become established in the southern part of the province. It does not appear to cause serious trouble in warm, dry soils. The disease is caused by the fungus *Spongospora subterranea*, which may persist in the soil for years.

Pale brown, raised, pinhead-sized pustules develop in the tubers and later enlarge to about 5 mm in diameter; the diseased tissue becomes jelly-like. Later the skin over the spot breaks and reveals a brown or greenish, powdery mass of fungus spores. A dry rot sometimes occurs about the pustules.

Control

- (1) Avoid low, cold wet soil.
- (2) Plant Certified seed.

Dry Rot in Storage in recent years has caused severe losses in some storages, with grade-out approaching 25%. The causal fungi are various species of *Fusarium*, in particular *sambucinum* and *coeruleum*.

The disease is probably present to some extent each year in most potato growing areas and can assume serious proportions if weather conditions are suitable for the causal organism at harvesttime.

Sunken, shriveled, wrinkled or broken areas occur at any point on the tuber surface. The extent of internal decay cannot be judged by the size of spot on the surface (Figure 14). Cutting affected tubers often reveals cavities (Figure 15). The broken-down tissues are brown to black. Frequently the cavities are lined with white, pink or yellow tufts of the fungus.

Although the rot is normally dry and brittle, it may be wet and jelly-like or mushy and leaky; it is never slimy. Frequently the entire central portion of the tuber is affected, resulting in a hollow shell. The color of the rot is often influenced by storage temperature, being lighter colored at higher temperatures and quite dark at lower ones.



Figure 14



Figure 15

The source of inoculum is the soil in which the crop was grown. Although infection may take place before harvest, most occurs at harvesttime through wounds caused by the digger and subsequent handlings.

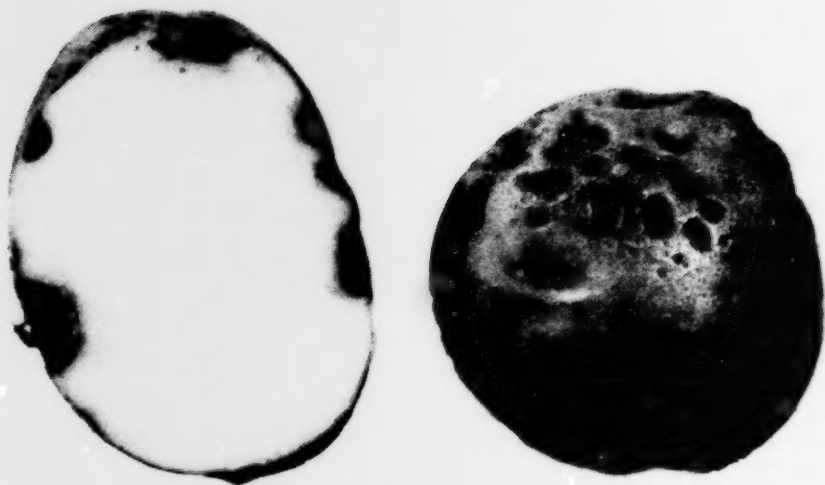


Figure 16

Control

- (1) Avoid injury and bruising at digging time.
- (2) To facilitate wound healing, the storage should be held for 10 to 14 days at the beginning of the storage period at 15 to 18°C with a high relative humidity. If the wounds heal quickly, less infection will take place. The relative humidity in the storage should be as high as possible without causing condensation of moisture on the tubers at any time during their storage life.
- (3) Practise as long a rotation as possible (at least two years) on fields where the diseased crop was grown. While most infection comes from infected seed pieces, some comes from the organism already established in the soil.

Phoma Rot has become prevalent in Prince Edward Island, New Brunswick, Quebec and Ontario during the past few years. It may develop into a major storage problem. The causal fungi are *Phoma spp.* The disease is favored by high soil moisture at harvest.

Phoma rot somewhat resembles Fusarium dry rot, but only part of the tuber will be affected. The spots are usually not much larger than a thumb print and never penetrate deeply into the tuber. The spots on the surface are circular, brown to gray and slightly sunken. Cracks may appear in the skin over the lesions. Underneath, the tissue is black, shrunken and decayed. If the black tissue is removed, a shallow cavity is evident which is bordered by healthy tissue (Figure 16).

Infection takes place through wounds caused by rough handling during digging or, in northern regions of the province, through powdery-scab lesions. It is spread by infected seed and will build up rapidly with continuous potato culture. Immature tubers appear to be more susceptible.

Control:

- (1) Crop rotation with grain or corn.
- (2) Buy good seed. Do not plant seed infected with Phoma rot. It is hoped that the Elite seed program will effectively control this disease.
- (3) Avoid injury and bruising at harvesttime.

Virus diseases

Leaf Roll is of major interest to seed growers. However, table-stock growers should be able to recognize the disease in order to evaluate the quality of seed purchased and to appreciate the advantages of Certified rather than home-saved seed. The causal organism is an aphid-borne virus.

Losses vary with the amount of leaf roll present in a field; 100% infection may cause a yield reduction of 60%.

Infected seed pieces do not break down during the growing season and may fail to produce a plant. Plants that develop from infected seed pieces are smaller than normal. The lower leaves first show an upward, lengthwise curling of the leaflets. This rolling progresses upward on the plant until all the leaflets show symptoms (Figure 17).

Rolled leaves are leathery, brittle or rigid, paler than healthy leaves, and frequently are reddish- or purplish-colored. The tubers are attached close to the stem, and are fewer and smaller than those on healthy plants of the same age.

With Russet Burbank, and to some extent Cobbler, a net necrosis develops in the tubers. This consists of a network



Figure 17

of small brown strands of discolored tissue, usually more prominent at the stem end, but frequently found throughout the entire tuber (Figure 18).

The virus is spread from diseased to healthy plants chiefly by the peach aphid and to a lesser extent by other species. Once an aphid becomes viruliferous (i.e. capable of infecting a healthy plant) it remains so for the rest of its life. Infected plants do not show any symptoms for at least 14 days after inoculation; and if the plants are infected late in the season, symptoms may not appear before harvest.

Viruliferous, winged aphids moving into a clean potato field are unlikely to be killed rapidly enough by either systemic or foliage aphicides to prevent infection, unless they arrive immediately after a field has been sprayed. The main value of these insecticides is in preventing aphids from becoming established and multiplying in the field, thus reducing the chance of inter-field spread of the leaf roll virus.

Control

For the Seed Grower:

- (1) Rogue all leaf-roll plants and put them in a sack so that the aphids cannot escape; remove the plants from the field and destroy them.
- (2) Control aphids — initially by systemics; later by foliage sprays.
- (3) Apply a top killer in time to prevent infection late in the season.
- (4) Isolate seed fields from non-certified potatoes.

For the Table-stock Grower:

- (1) Plant Certified seed.
- (2) Use an insecticide recommended for aphids. This is particularly important if you are growing Russet Burbank.

Mosaic viruses A and X, either singly or combined with each other and/or other viruses such as S, M and Y, will produce a mottling of the leaves which may vary from slight (mild mosaic) to severe (rugose mosaic). The latter is accompanied by severe stunting of the plant and the formation of few tubers. Seed growers should

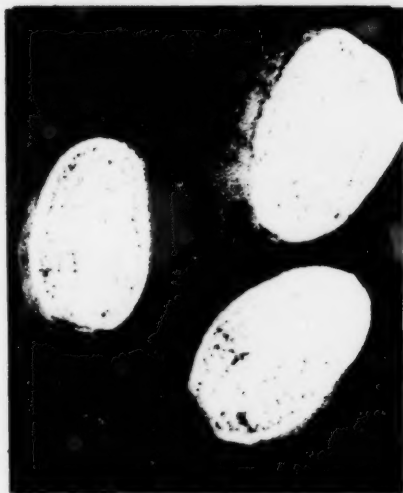


Figure 18

rogue all plants showing these symptoms and table-stock growers should check the amount in the crop to be sure that they have purchased good seed.

Purple-top or bunch top is caused by the aster yellows mycoplasma and is spread by leafhoppers. Terminal growth may appear bunched; the terminal leaflets roll up at the margins and assume a purplish color in dark-flowered cultivars and yellowish in light-flowered cultivars. The leaves may be rigid at first; later the tops wilt and a vascular discoloration may develop in the lower part of the stem and in tubers. The disease is readily confused with *Rhizoctonia* disease, *Verticillium* wilt or *Fusarium* wilt.

Control

Control the six-spotted leafhopper.

Spindle Tuber virus is spread in the field by aphids, flea beetles, tarnished plant bugs, grasshoppers, and any machinery which comes in contact with the plants as it moves through the field. It is spread from tuber to tuber by cutting knives and pick-type planters.

Infected tubers tend to be cylindrical and more pointed at the stem end than normal. The eyes are shallower or may protrude and are more numerous. Plants are more upright and leaves more erect than normal. There is no mottling of the leaves, which are often darker green than normal.

Control

Plant Certified seed. Growers of table-stock potatoes frequently buy Certified seed and save some of the crop for use as seed tubers for the succeeding crop. Because viruses and other diseases may increase very rapidly under such conditions, only Certified seed should be used.

Non-pathogenic problems

Sunburn, Sunscald, and Greening Potatoes exposed to natural or artificial light soon turn green. Parts of tubers exposed for a long time in the field become sunburned and turn dark green; the tissue beneath becomes yellowish and may taste bitter and be poisonous. Potatoes exposed to the sun during very hot weather may be sunscalded: the affected tissue is killed, turns watery and becomes brown. Potatoes affected by sunscald usually rot.

Control

(1) Attention to hilling will reduce sunburn to a minimum.

- (2) If the weather is very hot during digging, do not leave the potatoes exposed for more than an hour.
- (3) Reduce the use of electric lights in storages to a minimum.

Hollow Heart usually occurs when conditions favor very rapid growth of tubers. While it most frequently occurs in oversize tubers, smaller ones may suffer from the disorder. The cavity which develops in the center of the potato can be detected only by cutting it open. The tissue around the cavity may turn brown, but normally there is no decay.

Control

Closer spacing of seed will help reduce the occurrence of this condition on soils which tend to produce tubers with hollow heart.

Blackheart is due to insufficient oxygen and may occur if temperatures are too high, or if there is inadequate ventilation during shipment or in storage. One or several irregularly outlined, dark gray to purple-black areas develop in the tissue of the tuber. These may extend to the surface. Affected tissues are readily invaded by bacteria and fungi that soon cause various forms of decay. If the affected tissue dries, cavities develop and the tissue becomes tough and leathery.

Control

- (1) Oxygen must be supplied to internal tuber tissues faster than it is used by respiration. Ensure oxygen supply by daily ventilation of the stored potatoes. Ventilation should commence as soon as storage filling begins.
- (2) Temperature control in storage or in transit is also important in reducing blackheart. Excessive temperatures increase the respiration rate and reduce oxygen available to the tubers.

Enlarged Lenticels on tubers are caused by wet soil. A white, corky growth develops about the enlarged lenticels and later turns light brown. The condition is often seen on muck-grown potatoes and even on high land when very wet weather precedes harvest.

Stem-End Browning In affected tubers the vascular bundles at the point of attachment to the rhizome are brown to black and the discoloration extends for variable distances into the tuber. Browning has been associated with the use of chemical top killers that kill too rapidly and with frost killing the tops. Similar browning may be due to *Verticillium* wilt and other causes.

Growth Cracks are caused by uneven growing conditions. If very favorable mois-

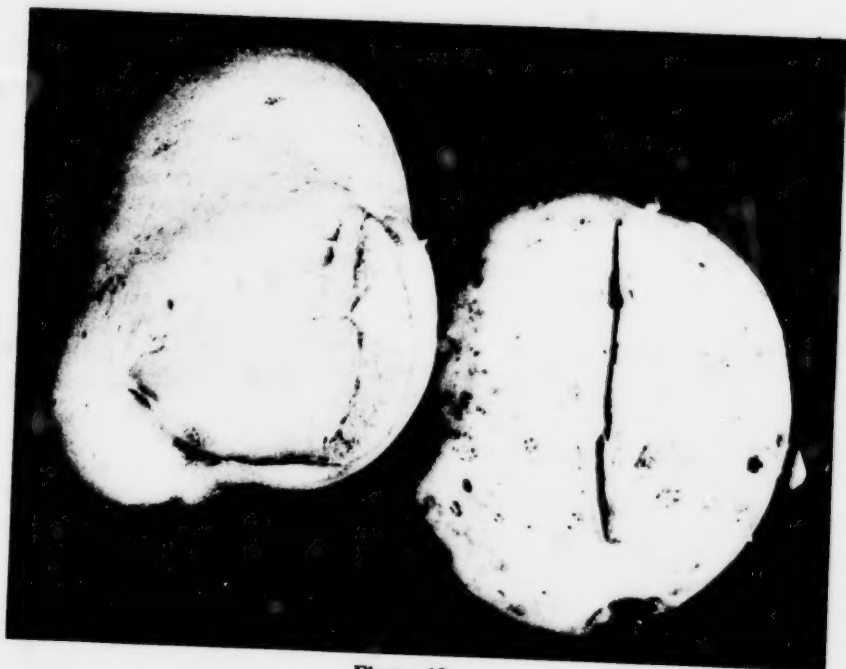


Figure 19



Figure 20

ture and temperature conditions follow a period of slow growth, splits may occur in the rapidly expanding tubers. Uniform stands of plants and practices which tend to promote even growth help to reduce the incidence of growth cracks (Figure 19).

Low-Temperature Injury symptoms vary with the temperature and the period of exposure. Tubers stored for a considerable time at 0 to 5°C develop a sweetened flavor because of the accumulation of sugar in the tissue. Long storage at a temperature close to freezing may result in a brownish discoloration of the tissue. Exposure to freezing temperature at harvesttime or in storage may result in browning of the vascular ring, particularly at the stem end of the tuber; if the exposure is longer, a brownish netting occurs throughout the tuber, and finally gray to black discolored patches appear (Figure 20). Frequently, there is a bluish-gray tinge to the brown discoloration. Frozen tubers break down into a soft, watery rot after thawing.

INSECTS

This section has been prepared with the assistance of officers of the Entomology Division, Agriculture Canada. The illustrations of the Colorado potato beetle and aphids are through the courtesy of Agriculture Canada.

The most important insects that feed on the foliage of potatoes in Ontario are the Colorado potato beetle, potato flea beetle and potato leafhopper. Aphids are a problem at times. The tarnished plant bug and cutworm are less important. In northern Ontario blister beetles occasionally cause defoliation.

Tubers may be injured by wireworms, white grubs, the larvae of flea beetles and slugs. White grubs and wireworms are by far the most important.

Control

See OMAF Publication 363, *Vegetable Production Recommendations*.

LEAF-FEEDING INSECTS

The Colorado Potato Beetle is a constant threat to the potato crop unless treatment is given. In recent years it has become more abundant and is now a pest of major importance.

Injury Both adults and larvae eat the leaves, the larvae causing the greater damage.

Life cycle This insect spends the winter in the adult stage in the ground where the potatoes were grown. The beetles fly to the new potato fields about the end of May, where they lay clusters of yellow eggs on the underside of the leaves. These hatch into slug-like larvae that feed on the leaves, eventually leaving only the stem and main branches. In two or three weeks the larvae are mature. They enter the ground, pupate, and in a little over a week some emerge as adults. There is a partial second generation. The beetles from both first and second broods feed on the foliage until fall when they go into the ground for the winter.



Figure 21 — Colorado potato beetle. Leaves eaten by the adult (striped form) and its larva (just below the beetle)

The Potato Flea Beetle is a small, black beetle about the size of the head of a pin. it jumps from the leaves when disturbed, hence the name.



Figure 22 — Potato flea beetle injury

Injury The beetles eat small holes in the leaves, giving them a shot-hole appearance. The injury is more severe and destructive when the plants are small, but may be very conspicuous in August and September. These beetles carry the organisms of some virus diseases, such as spindle tuber and unmottled curly dwarf, in addition to making leaf punctures through which fungus organisms may gain entrance.

The larvae sometimes attack the tubers. This feeding may result in small, brownish, corky areas that may be flat, sunken or pimply. When these corky areas are cut, they are found to extend into the flesh of the tuber.

Life cycle The adults spend the winter in any good hiding place. Early in the spring, the beetles fly to potatoes, tomatoes and other host plants. They lay eggs in the soil under the plants, especially potato, in June and July. The larvae feed on the roots and occasionally the tubers. The mature larvae pupate in the soil and adults emerge in August. These new beetles feed on the foliage in August and September before going into winter quarters.

Potato Leafhoppers are small, greenish-white insects. Both the nymphs and adults suck juice from the leaves. The nymphs, or young hoppers, look like aphids but do not have cornicles (tube-like structures) on the abdomen, and they move very quickly, usually sideways, on the leaves.

The main species on potato are the potato leafhopper and the six-spotted leafhopper.

Potato Leafhopper

Injury When feeding, it injects a poison into the leaf that causes it to turn yellowish green and curl upwards. Severe damage may cause defoliation. This injury is known as hopperburn.

Life cycle The adults migrate from farther south each spring. They may be seen early in the season on alfalfa, apple, bean and other plants. Later they migrate to potatoes. Eggs are laid in the stems and larger veins of the leaves. These hatch into nymphs that feed on the leaves for about two weeks before becoming mature. There is a second generation in August.

Six-spotted Leafhopper

Injury This insect does not inject a toxin or cause the hopperburn characteristic of the potato leafhopper. It is important in the spread of disease. Yellow dwarf and purple-top may be spread by this insect.

Life cycle The insect overwinters in the egg stage on winter cereals. Young nymphs develop on the grains in the early part of the season and when they become adult

migrate to potatoes and other crops as winter grains mature. Normally there is also a migration from the south each year so that populations may develop quite early in the season. There is a second generation in August.

Aphids only occasionally attack potatoes severely in Ontario.

Several species, especially the green peach aphid, the potato aphid, and the buckthorn aphid, cause damage. Most aphids attacking potatoes are green, but the potato aphid has a pink tinge. All are small, soft-bodied insects with a pair of cornicles or tubes projecting from the upper, rear part of the abdomen. They are usually wingless but winged forms appear from time to time.

Injury Both nymphs and adults suck the sap from the plant, causing a loss in color and, if the damage is severe, stunting or death of the plant. Aphids spread virus diseases such as leaf roll, mild mosaic, rugose mosaic, spindle tuber and unmottled curly dwarf. In an average year they are more important because of virus transmission than because of the direct damage they cause by killing leaves and plants.

Life cycle Aphids attacking potatoes spend the winter in the egg stage on various host plants such as the rose, plum, peach and apple. In spring or early summer, female aphids fly from these hosts to the potato or to other plants, chiefly weeds, and later to the potato. On the potato they feed and produce living young. New generations are produced in rapid succession, most of them being wingless. Some



Figure 23 — Aphid injury

winged forms appear that fly to new plants either in the same or an adjoining field. In the fall winged males and females appear; they mate and the females fly to the original host plant to lay eggs for winter.

The Tarnished Plant Bug sucks plant sap and will cause blossoms to drop prematurely. It also may spread the organisms of spindle tuber and unmottled curly dwarf.

OTHER INSECTS

Cutworms occasionally cut off new shoots at ground level in late May and June. They are dark-colored caterpillars about 3 cm long, which come into the potato field from surrounding grassy areas or may have been in the soil since the previous fall. In addition to those cutworms that feed at or near ground level and cut off plants, the variegated cutworm may occasionally occur as a spotty infestation. This cutworm tends to feed on the foliage and since there are two generations, damage may occur when the plants are small and in late July. When full-grown, the larvae are about 3 cm long, smooth-skinned and mottled brown in color with a pale yellow



Figure 24 — Wireworm injury

dot in the mid-dorsal line of each segment.

Late generations of black cutworms may lay eggs on the developed potato foliage in late July or early August. These larvae sometimes attack and live on the tubers and have caused up to 10% culls.

Wireworms are hard, slender, yellowish to light brown "worms" measuring 1-2.5 cm in length. They have three pairs of short legs just behind the head.

Injury Wireworms make holes in the tubers about the size of the lead in a pencil. Occasionally the insects are seen with the head end in the tubers at digging time (Figure 24), but they leave the tubers very quickly after digging. Wireworm-injured tubers are of little value except for livestock.

Life history The adults are medium-sized, brown beetles called click beetles. They lay their eggs in the soil. The larval and pupal stages are spent in the soil. Some species develop from egg to adult in one year, whereas others may take four or five. Nearly all this time is spent in the larval stage, the form that causes the injury.

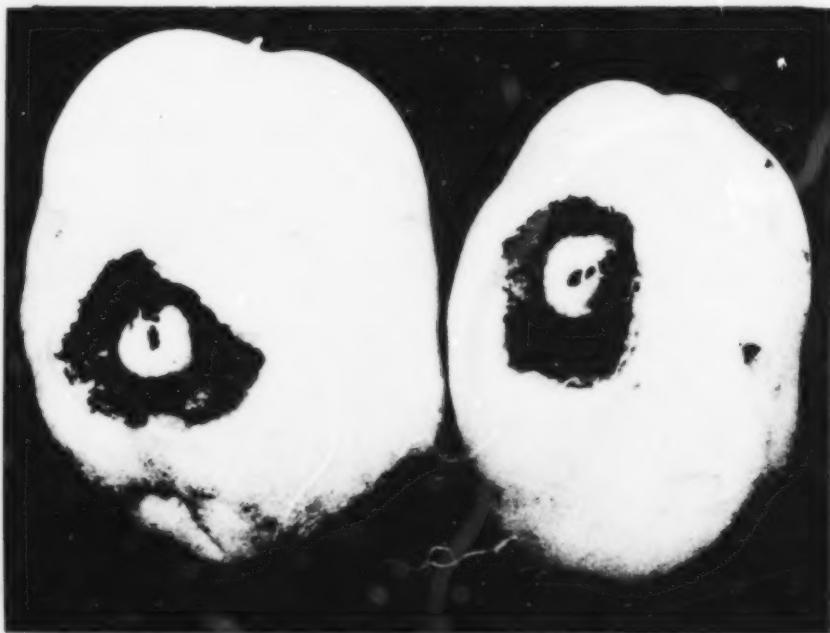


Figure 25 — White grubs and injury

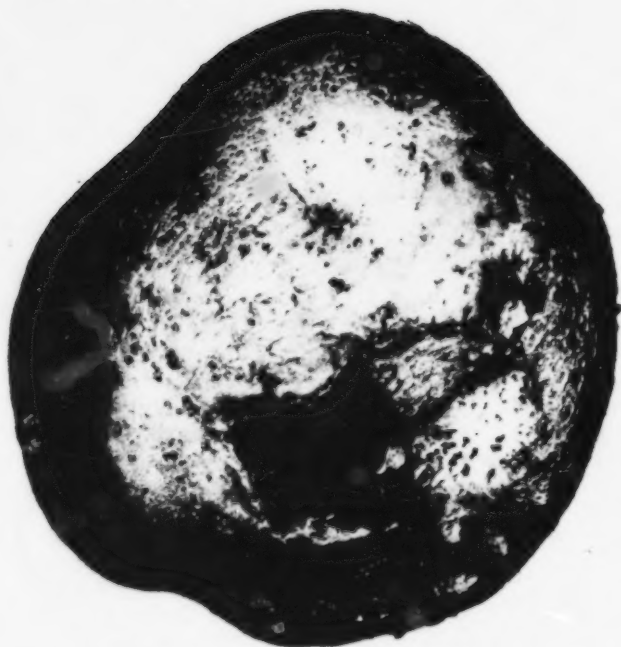


Figure 26 — A slug and injury

White grubs are the young, or larvae, of May or June beetles. They are generally more plentiful in land plowed from sod. Land that has not been in sod for two or three years is usually free from grubs, except sometimes in a year following the heavy beetle flight, when injury may follow fall wheat and some other crops. White grubs prefer light, sandy land. They are rarely a pest in heavy, poorly drained soil. Second-year grubs, the stage that causes nearly all the damage, are about 3 cm long and grayish-white with light brown heads and legs; they lie in the ground in a curved or C-shaped position. Potatoes are one of their favorite crops, the grubs gouging the sides of the tubers.

Life history White grubs have a three-year cycle. The adults lay eggs in May and June in grass sod, lawns and weedy areas of cultivated crops. These hatch into small, white grubs that feed very little in the first summer and remain inactive in the soil over winter. In the second summer the two-year grubs feed voraciously, increasing greatly in size and causing severe damage. They remain in the soil as nearly full-grown grubs for the second winter. In the spring of the third year these large grubs feed a little but cause only slight damage. They change into pupae in the

ground during the early summer and transform to inactive adults later in the season. These adults remain in the ground through the fall and winter and emerge in the following May and June to complete the cycle.

Slugs feed at night on the foliage and tubers. The important injury is to the tuber, where cavities may be made similar to those caused by white grub feeding, except that in slug injury the uneaten potato skin remains over the cavity. Most of the damage in Ontario has been in home-garden plantings.

Commercial poisoned baits containing metaldehyde are effective in control. These baits are available to the home gardener through insecticide dealers.

HARVESTING

If a potato grower has planted good seed of a suitable cultivar, fertilized it adequately and protected it from insects and disease, and if soil moisture has been sufficient throughout the growing season, there should be a high yield of high-quality potatoes. Unfortunately, many such yields are seriously reduced by the handling of the crop between harvest and consumption.

Surveys in city retail stores (where 80% of the crop is sold) have shown that at least half the damaged tubers found in various packs were injured at harvesttime. This unnecessary waste could have been avoided easily by careful digging and handling. More serious is the damage to the reputation of Ontario potatoes caused by failure to grade out damaged tubers.

The proper time for harvesting is when the crop is mature, but the actual time may be influenced by market prospects, weather conditions and the availability of labor. Potatoes should not be dug until at least two weeks after the vines are dead. This allows the skin of the tubers to become tougher and should reduce the degree of skinning and bruising. However, even when digging a mature crop, precautions should be taken to reduce damage by following a careful harvesting procedure and by padding certain areas of the machine.

With the use of more effective insecticides, better control of the potato insect population is possible. This has led to a lengthening of the growing season and delayed maturity. If late potatoes are harvested when the tops are still green, not only is the amount of skinning and bruising increased but also, in the case of infection of foliage by late blight, the tubers are more likely to be contaminated, with a resulting late blight tuber-rot in storage.

If the vines remain alive too late in the season or become infected with late blight, the use of chemical vine killers is advised. All may be applied with regular spray equipment. The manufacturer's directions for each should be followed closely.

Cultivars with large, vigorous tops, such as Kennebec, are hard to kill, especially when there is plenty of moisture available.

The use of rotobeaters or rotary mowers is recommended only to make digging easier by shredding vines and any tall weeds after they have been killed.

Beating or cutting off green tops still leaves 2 or 3 cm of green stalk above the ground; this can sprout again if moisture is plentiful, but even if it does not do so it can still become infected with late blight from which the spores can be washed down to the tubers.

Vine-killing is becoming increasingly important to growers of seed because an early kill controls tuber size and reduces the spread of virus diseases by certain insects late in the season.

Various types of potato-harvesting combines are now being used. These machines remove vines and stones mechanically and deliver sized tubers into containers or into bulk trucks driving alongside.

Much of the tuber injury during harvesting is caused by improper operation or adjustment of the digger or combine. Rough handling and mechanical injury result in grade reductions that no grower can afford.

This is especially important in the harvesting of early potatoes. Wherever possible, field grading and packing into compact, rigid containers should be carried out together with low speeds of harvesting and grading machinery.

Rubber protection on all parts of the equipment which come in contact with the potatoes, plus minimum handling of the crop, are very important in preventing excessive bruising and subsequent discoloration.

Methods of handling potatoes after they are dug vary with different growers, but most use trucks and wagons for bulk-handling directly from the combine, especially on large areas. Special care is needed under these conditions to prevent damage by bruising when loading and unloading. Too few growers pay sufficient attention to this aspect of handling the crop and so market an inferior product or have an unnecessarily high grade-out.

STORAGE

A properly designed potato storage usually will pay for itself in a few years through higher-quality potatoes which command a better price. It is not always necessary to build a completely new storage; in some instances, the present improvised storage can be converted into a good storage through some alterations, insulation and a planned system of ventilation and air circulation.

Potato storage structures

The Canadian Farm Building Plan Service has prepared a *Catalogue of Plans for Fruit and Vegetable Buildings and Equipment*. This contains plans for potato storages and may be obtained free from your county agricultural office or from the Agricultural Engineering Service, Guelph Agricultural Centre, Box 1030, Guelph, Ont. N1H 6N1.

Specialists of the Agricultural Engineering Service, Ontario Ministry of Agriculture and Food, are available for advice on problems in the construction, insulation and ventilation of potato storages.

For the purposes of discussion, the storage life of potatoes may be divided into three periods: curing, resting and sprouting.

Curing period At harvesttime, potatoes have a poorly developed periderm (corky skin). Considerable care is necessary to minimize bruising, cutting, and skinning when harvesting and filling the storage. Injuries will cause weight loss and the occurrence of rots in storage unless the tubers are cured immediately.

Curing the potatoes, i.e. maintaining the storage for 10 to 14 days at a temperature of 15 to 18°C and very high (90 to 95%) relative humidity, results in thickening of the corky periderm and rapid healing of cuts and bruises. All potatoes, whether for seed or table use, should have a curing treatment when put into storage.

Rest period Following harvest, potatoes have a rest period of 8 to 14 weeks during which they will not sprout. In general, shorter rest periods result from the use of early cultivars, early planting and harvesting, dry weather near harvest and a rather high or fluctuating temperature in the storage.

During the rest period, potatoes retain their highest quality for table use and chipping when the storage is maintained at 10°C and high (90%) relative humidity (see page 44, *Chemical Changes During Storage*). Potatoes held at 10°C should be marketed during the rest period or soon afterwards because, after finishing their rest period, they sprout readily. Lowering the storage temperature to 5°C near the end of the rest period will retard sprouting and permit a slightly longer marketing interval. This is not recommended for potatoes destined for chipping.

As an alternative, tubers for fresh market or processing may be treated with a chemical sprout inhibitor near the end of the rest period, e.g. mid-December, to prevent sprouting if longer storage is desired.

Potatoes intended for marketing as table stock from midwinter to late spring should be cooled to 3-5°C as soon as possible after curing. The temperature should be kept at this level together with a high relative humidity throughout both the rest

period and subsequent sprouting period.

Seed potatoes store satisfactorily under the same conditions as potatoes held for late-winter marketing but a storage temperature as low as 2°C is not harmful, and may be of benefit both in controlling sprouting and rotting and in reducing water loss. Storage temperatures below 2°C may result in low-temperature injury and poor germination after planting.

Seed potatoes should not be kept in the same building as potatoes treated with chlorpropham, nor should they be stored in containers which have been used for chlorpropham-treated potatoes the previous year.

Sprouting period Potatoes sprout readily after completing their rest period. However, sprouting can be checked by a 3-5°C storage temperature treatment with a chemical sprout-inhibitor.

Sprouting is very undesirable for several reasons. The respiration rate of the sprouting tuber increases, giving off extra heat (loss of dry matter), extra water (shrinkage, if uncontrolled by humidity) and may result in pressure-bruising, a condition in which potatoes lose some of their rigidity and push into one another, causing dents. This is accentuated by piling potatoes too high.

Bacterial rots and fungal dry rots as well as fruit flies are more active at these higher-temperature "hot spots".

Sprouts can be removed easily by modern graders but shrinkage losses from sprouting age the potato, giving it a flabby skin and an undesirable appearance to the consumer.

Chemical sprout inhibitors

The advantage of treating potatoes to inhibit sprouting is that treated potatoes can be stored at 10°C or higher during their sprouting period rather than at the 3-5°C temperature necessary to stop sprout growth.

Maleic hydrazide is a growth-regulating substance which has proved very useful as a sprout inhibitor. It should be sprayed on the potato plants about two to three weeks after full bloom. The potato foliage should not be under stress and still green for good translocation to the tubers. Apply at least two weeks before chemical top killing. Application too early can result in reduced tuber size, so consult the product label for specific cultivars. **Maleic hydrazide should never be applied to potato crops destined for seed.**

Once in storage, tubers from a crop treated with maleic hydrazide will not affect seed potatoes stored in the same storage.

Chlorpropham is another growth regulator which is being used widely as a sprout inhibitor. It is applied to the tubers by various methods (dip, spray, aerosol, etc.) usually just before sprouting begins. Also, tubers removed from a 3-5°C storage temperature may be treated before packaging for market. Chlorpropham should not be applied until the potatoes are cured as it interferes with the curing process.

See OMAF Publication 363, *Vegetable Production Recommendations* for sprout inhibitors.

Importance of humidity

Newly harvested potatoes can suffer a high rate of evaporation of water until their corky periderm has formed. To reduce water loss and shrinkage as much as possible, it is important to maintain very high humidity (90 to 95%) in the storage during the curing period. Moreover, the very high humidity speeds up periderm formation and the wound-healing process.

Development of the corky periderm gives potatoes a reasonably effective natural barrier against water loss. Nevertheless, tests show that a relative humidity of at least 90% is necessary to minimize shrinkage. Dry storages always cause excessive evaporation of water from potatoes, with a consequent loss in weight and often pressure bruises.

Modern potato storages built above ground, with cement floors, and equipped with powerful ventilation systems, usually require that moisture be added to the ventilation system to keep humidity at the 90% level.

Chemical changes during storage

A chemical change of great practical importance that may occur during storage is the conversion of starch into reducing sugars.

Newly harvested potatoes of good quality normally have a high starch content and very little sugar. When baked or boiled, the potatoes are very palatable, being white, mealy, and bland in flavor. As chips or French fries they have a desirable, light golden color.

A chemical change of starch to reducing sugars occurs when potatoes are stored at a temperature of less than 10°C, and the rate of change increases as the storage temperature is lowered. Potatoes which have accumulated too much sugar during storage do not produce high-quality cooked products. When baked or boiled, they have an undesirably sweet taste, soggy texture and poor color. When they are processed for chips or French fries, caramelization of the sugar by the heat of the cooking oil causes a darkening of the product.

It is customary now for potatoes used for chipping to be treated with a sprout inhibitor and stored at 10°C or slightly higher. Most of the crop held for table use is stored at 3-5°C to prevent sprouting, and reliance is placed on the higher temperatures encountered during marketing for some improvement in quality.

Temperature reconditioning for improved quality

It has long been known that the cooking qualities of stored potatoes can be improved by placing them in 15 to 20°C temperatures for one or two weeks previous to use. The improvement is effected by the chemical conversion of a considerable portion of the sugar accumulated during storage back into starch. Although temperature reconditioning or "warming" the potatoes is a recommended practice, it has certain disadvantages. Weight losses due to evaporation are usually considerable during the reconditioning period unless the relative humidity is kept at 90% or higher. The temperature used for reconditioning permits rapid sprouting, especially late in the storage season. Finally, as potatoes cannot be reconditioned to their original quality level, the temperature reconditioning method, though beneficial, cannot be considered a cure for potatoes stored at low temperatures.

Storage management

A potato storage may be carefully planned and constructed but it will not be a success unless it is well managed. The operator should understand the temperature and humidity requirements of stored potatoes and give careful attention to the details of storage management.

Sanitation The storage requires a thorough cleaning and disinfecting each year well in advance of the filling operations.

Filling The potatoes should be examined carefully as filling operations proceed and only sound, disease-free tubers retained for long storage. Questionable lots of potatoes should be placed in separate bins and graded as soon as possible to remove unmarketable tubers.

For gravity filling in older-type potato cellars use canvas chutes or padded slides. In regular ground-level storages mechanical bin loaders or pilers with adjustable or telescoping conveyors are of great assistance in filling the storage. These often have a grading area on the conveyor. Frequent moving of the bin piler boom from side to side when filling reduces the chance of pockets of dirt or small potatoes being established that could impede ventilation through the pile of stored potatoes, and encourage "hot spots" later in storage.

Operation The temperature and humidity requirements of stored potatoes previously discussed, may be summarized as follows:

1. After the storage is filled, give the potatoes a curing temperature of 15-18°C and very high (90 to 95%) relative humidity for 10 to 14 days.
2. After the curing treatment, reduce the storage temperature and humidity to one of the following conditions:
 - (a) 10°C and 90% relative humidity (1) for potatoes to be marketed within three months for food, and (2) for the entire storage period of potatoes for chipping;
 - (b) 3-5°C and high relative humidity for potatoes not treated with a sprout inhibitor and to be marketed after three months for table stock;
 - (c) 2-4°C and high relative humidity for seed potatoes.

Temperature control of a refrigerated storage may mean simply setting an accurate thermostatic control. The following description is for a storage with cooling by outside air.

For the curing treatment, the storage is tightly closed. Ventilation may be necessary to prevent the storage temperature going above 18°C and to supply oxygen to the pile, as well as to remove carbon dioxide produced by the respiring potatoes.

After the curing treatment, cool the potatoes one half to one degree a day to the desired storage temperature. This is a minor problem for the operator when the ventilation and air-circulation systems are equipped with automatic controls. If manual controls are used, the operator must give considerable attention to starting ventilation when it is colder outside the storage than inside and, of equal importance, stopping ventilation when it is warmer outside. As a guide for ventilation, a reliable thermometer must be located outside the storage as well as one inside. When the storage has been cooled to the desired temperature, very little ventilation should be necessary to maintain it at the proper level.

The importance of maintaining high humidity has already been stressed. A sling psychrometer is a useful instrument for determining the relative humidity at regular intervals. Ventilation air should be at the 95% relative humidity level unless the stored potatoes are under stress from problems such as late blight, frost damage, or very wet harvest conditions. To maintain this high relative humidity, in most storages, water needs to be added to the air or the ventilation air will take the water from the potatoes. Simple methods such as watering exposed cement floor areas frequently or keeping water in below-floor-level ducts are helpful. In most cases, however, power-driven humidifiers are necessary to keep the ventilation air humid enough. If the storage ceiling or any surface like an outside wall is cooler than the inside storage air when there is 95% relative humidity, condensation will take place. To overcome this problem a constant air flow across the ceiling may be required.

When condensation on the ceiling and walls of the storage creates a problem, it is not necessarily an indication of too high humidity. Usually the cause is insufficient insulation and/or poor air circulation.

MARKETING

The difference between profit and loss to an Ontario potato grower depends more on marketing than on any other single factor.

In Ontario there are two growers' boards involved in the potato market.

The Ontario Potato Growers' Marketing Board, established in 1976, negotiates the prices, terms and conditions of sale of potatoes sold to the processing industry. Five categories, i.e. chips, frozen French fries, dehydration, soups and stews, and pre-peel are negotiated by committees of growers and processors.

Prices are negotiated in February and contracts are usually signed in early spring for delivery to processors starting at harvest.

The Ontario Fresh Potato Growers' Marketing Board, established in 1979, sets the price paid to producers for fresh potatoes grown in Ontario. The price is established through the use of a pricing committee which meets weekly.

The Fresh Board also is involved in the promotion of the Ontario industry and the improvement of potato quality. Potato growers in Ontario support both boards with a fee paid on all potatoes marketed, except seed.

The Ontario potato market is quite complicated, with supplies available from local farms, the Maritime Provinces, and the United States. The market is dominated by supplies from these sources on the following pattern each year:

- (a) Up to June 10, the only new potatoes available are from the United States, mainly California and Florida. There is a duty on all imported potatoes throughout the year.
- (b) From June 10 to about September 1, early potatoes supply most of the market and some are sent out of the province.
- (c) Ontario late potatoes are present on local markets for the remainder of the season, but retain a strong hold on the larger city markets during the winter months and used to sell at a premium over local supplies until the Ontario Fresh Potato Board was organized, but now the price is similar.

Uniformly high quality is also essential to establish preference by both retailers

and homemakers. This is ensured by strictly enforced marketing regulations. Ontario regulations for the marketing of the main crop are just as comprehensive as any other but, owing to the large area involved and the large number of wholesale outlets, they are difficult to enforce without the complete and wholehearted support of all growers. Orderly marketing of a consistently high-quality product is the only way to ensure a steady demand and a fair price.

Early potatoes demand special consideration inasmuch as they are very susceptible to skinning, bruising and discoloration. In view of the highly perishable nature of the early crop, only a minimum amount of handling and utmost care in harvesting, grading and packaging operations can ensure good market quality.

One factor in the marketing of the crop which is becoming important is the washing of potatoes, particularly in the case of the early crop. This is an extra operation which adds to the cost of the product. That it is justified is shown by consumer acceptance in the United States and in those parts of Ontario where washed potatoes are marketed in vented polyethylene or paper bags.

UTILIZATION

The per-capita consumption of potatoes in Ontario, which has shown a decline since records have been kept, is now on the increase. Processed potatoes are the strongest factor in this readjustment; they now account for 50% of all consumption. Potato chips are the most popular form of processed potatoes, closely followed by frozen French fries. Potato flakes and other forms of processed potatoes are now being manufactured in Canada, and a further increase in consumption may be expected.

QUALITY

Potato quality may be considered under two headings — market quality and cooking quality. Market quality involves overall evaluation of the external characteristics, and cooking quality the internal characteristics.

Market quality

Market quality is most effective in influencing consumer preference or salability. To most buyers, a good potato is clean, bright, uniform in size and shape, with shallow eyes, smooth skin and firm flesh. Deep eyes, irregular shape and surface defects are undesirable because they cause waste in preparation, but they are not necessarily associated with poor cooking quality or low food value.

Under the present marketing regulations in Ontario, table-stock potatoes are sold by grade, e.g. Canada No. 1, Ontario No. 1, etc. However, the cultivar name is

seldom marked and few retailers know which cultivar is being sold. Studies conducted by both Agriculture Canada and the Ontario Ministry of Agriculture and Food have shown that all too often packaged potatoes do not come up to the labeled grade. Lack of market quality is caused more often by tuber defects than by improper grading for size.

Some tuber defects which may be present in various combinations are sunburn, second growth, growth cracks and scab; injury due to wireworms, white grubs, slugs and twitch grass; late blight, various storage rots, net necrosis, hollow heart and stem-end browning; skinned, bruised and cut tubers and black spot. Dirt on potatoes often covers many of these defects, but they will show when the consumer washes and peels the potatoes.

The use of transparent containers increases the confidence of the consumer. There are still problems to be overcome in the use of transparent packages for potatoes, mainly concerned with greening under lights in modern markets, but the use of amber-colored plastic largely overcomes this, besides making the tubers more attractive. The grower who produces high-class table stock will reap the benefit. Eventually the bag may also carry the name of the cultivar and indicate the purpose for which it is best suited.

For those who consider this type of marketing not necessary for potatoes, the following is worthy of consideration:

- (1) 75% of all Ontario table potatoes are retailed by supermarkets.
- (2) The potato is the only commodity among the hundreds on display which is not marketed in a clean, attractive condition.

Many defects are mainly attributable to poor harvesting and storage practices. Common scab is probably the outstanding exception to this statement. A grower who plants a susceptible cultivar on a known "scabby" soil must be prepared to accept a high grade-out.

Cooking quality

If the homemaker has been persuaded to buy superior-looking potatoes, it is equally important that they should be superior-cooking potatoes. Eye appeal is important but equally so are the texture, color and flavor of the cooked product.

Texture is usually referred to in terms of mealiness or sogginess. Mealiness is commonly associated with high dry-matter content, indicated by the specific gravity of the raw tubers. Good baking potatoes should have a specific gravity of 1.080 or above. Those most suitable for boiling are in the 1.070 to 1.079 range, and those most suitable for pan-frying are below 1.070.

For best quality, it is generally agreed that boiled, mashed, and baked potatoes should be creamy white in color, moderately dry and mealy in texture and have a natural potato flavor. Boiled potatoes should be free from sloughing.

Some of the more important factors affecting the cooking quality of potatoes are cultivar, soil type, season, date of planting, amount and analysis of fertilizer, spraying program, vine killer and date of harvest.

Experiments conducted in central Ontario showed that, for this region, mid-May planting gave the highest yields and also the highest specific gravity of the cultivars used. Planting too early tended to give a poorer stand with many oversize tubers, while late planting often resulted in immature tubers with a low specific gravity and very susceptible to skinning and bruising.

Several cultural experiments involving different rates and combinations of major fertilizer elements have been carried out both at the O.A.C. Horticultural Research Station and regionally in the late-potato-producing areas of southern Ontario over the past few years. The more important observations related to cooking quality may be summarized as follows:

- (1) Nitrogen applications up to 56 kg/ha had no effect on specific gravity. Higher rates slightly lowered the specific gravity but had little effect on color or flavor.
- (2) Fertilizer phosphorus had little effect on the texture, color or flavor of the cooked tubers.
- (3) On the average, increments of potassium above 56 kg/ha of K_2O tended to decrease the specific gravity. However, in 1956, 224 kg/ha decreased the specific gravity by only 1.4% below the zero rate, while the yield was increased by 168 kg/ha. It was also observed that each increment of K_2O up to 224 kg/ha improved the whiteness of the cooked product.

Recent studies in California, where there is an important export trade, have shown that adequate amounts of potassium are needed to resist the formation of internal black spot caused by contact and pressure bruises during harvesting and transportation.

The only hazard connected with vine-killing seems to be that of exceeding the recommended dosage. A rapid kill, under certain conditions, may cause discoloration of the stem end of the tubers, known as "stem-end browning". Time of harvesting is important only as it affects the maturity of the tubers, with its attendant factors of bruising, skinning and specific gravity.

Soil type combined with the prevailing weather has an important bearing on potato quality. The increased water-holding capacity and the higher nutrient

content of loam soils usually result in a higher dry-matter content of the tubers.

The season also has a great effect on quality. An even distribution of rainfall and moderate temperatures will give a high yield of smooth tubers with a high dry-matter content and white flesh when cooked. Excessive temperatures cause second growth, low specific gravity and a tendency towards after-cooking darkening. Plenty of rain following a prolonged drought will cause rapid growth resulting in rough-shaped tubers, growth cracks, hollow heart and reduced total solids.

PRODUCTION COSTS

The cost of producing potatoes is much greater than for most Ontario field crops. It is several times that for a crop such as grain corn and is more comparable with that for tomatoes.

Costs vary from farm to farm and with the kind of market supplied, but the following items must be considered where applicable: land rental, labor, fertilizer, land preparation, seed, seed cutting, planting, cultivation and hilling, fungicides, insecticides, herbicides, spraying operations, irrigation, vine-killers, sprout-inhibitors, grading, storage and marketing.

In addition, the grower must not forget depreciation, the cost of borrowing, the return on his investment and a management fee.

REGULATIONS UNDER THE FARM PRODUCTS GRADES AND SALES ACT RESPECTING TABLE-STOCK POTATOES REVISED 1980

The regulations made under The Farm Products Grades and Sales Act require that table-stock potatoes be properly graded, packed and marked before being sold or offered for sale in Ontario.

Because field-run potatoes vary in size and defects, careful grading, packing, sizing and marketing are necessary. The grading regulations, if adhered to, are beneficial to the potato grower and to the industry as a whole by increasing sales to satisfied customers and thus creating and maintaining stable markets.

Inspection services of the Ontario Ministry of Agriculture and Food are provided in producing areas and at the wholesale and retail levels to enforce regulations, and carry out educational programs in an effort to obtain the cooperation of the industry in improving the grade and quality of Ontario potatoes. While this assistance may be helpful, it remains the responsibility of the Ontario growers and packers to strive constantly for a product well above the minimum requirements.

Many growers who grade their potatoes properly find that they cannot dispose of their culls except by letting them rot on the cull pile. Apart from being a very dangerous source of disease, this is also very wasteful, as potatoes are excellent livestock feed. A grower who has no livestock of his own should be able to sell them to neighbors who have, to their mutual advantage. Details of the value of potatoes as feed, and methods of feeding are contained in OMAF Factsheet, *Potatoes as a Livestock Feed*, Agdex 400/60, available from your county agricultural office. The possible advent of central grading stations will concentrate supplies of culls, and livestock farmers should be prepared to take advantage of the situation.

Regulations respecting the grading, sizing, marking, packing and shipping of table-stock potatoes are subject to amendment. The complete regulations may be obtained from the following sources:

1. Fruit and Vegetable Inspection Branch, Ontario Ministry of Agriculture and Food, Legislative Buildings, Toronto.
2. Inspection Branch offices at Leamington, Vineland Station, Bradford, Brighton, Thedford, London, Simcoe, Waterloo, Alliston, Ottawa, Sudbury, Thunder Bay, and the Ontario Food Terminal, Toronto.

SEED PRODUCTION

The production of seed potatoes is a job for the specialist often working with a limited area. A thorough knowledge of insects and diseases is essential, together with a complete program for their control. Careful precautions must be taken at all times to ensure a high-quality product.

The Elite Seed Potato Program now in place is designed to provide stocks of virtually disease-free seed to commercial seed-growers so that they, in turn, can increase them for growers of table-stock or processing potatoes. This supercedes the old system in which seed could maintain its Foundation rating indefinitely on the basis of visual inspections in the field and in the bin. The program is based on: (1) starting with material that is as disease-free as possible; (2) dropping that material by a grade each year, even though it may still be "clean", thus, flushing out the system and adding new material each year, and (3) sophisticated pre- and post-harvest testing to ensure that the seed meets the standards for its grade.

The original material is obtained by selecting plants which are free from the spindle tuber viroid and growing them at 37°C for six weeks. This often enables the cells at the growing points to divide faster than the viruses which are in them. The exception is the spindle tuber viroid, which is why the plants must be free from the organism before the treatment begins.

These cells at the growing points, or meristem cells as they are called, are then

removed — a 0.3 mm slice is cut off with a sterile razor blade under a microscope — and placed in a sterile growing medium in a sealed test tube where, after several weeks, a complete plantlet is formed. This plantlet is then tested for the presence of bacterial ring rot and the common viruses, A, S, M, X, Y, leaf-roll and spindle tuber and, if clean, is transplanted to a 10-cm pot in an insect-proof greenhouse.

The resulting plantlets are often referred to as virus-free or VF plantlets and are used as the building block for seed multiplication. The Agriculture Canada laboratory at Vancouver, B.C. presently maintains a bank of VF seedlings and tubers from 50-60 candidate seedlings.

The new SPUD unit (Seed Potato Upgrading and Distribution Centre) at New Liskeard will be multiplying VF plantlets by tissue-culture methods. Plantlets grown in tissue culture will be entered into the Elite Seed system by first transferring the test-tube plantlets to soil under greenhouse conditions. Stem cuttings or tubers from these greenhouse plants will be planted in fields of selected growers in northern Ontario (areas having low levels of aphids for transmission of virus diseases).

The Elite seed produced will be used to grow Foundation and Certified seed.

The cultivars to be increased by the SPUD unit will be selected by the Ontario Regional Potato Committee, on which all segments of the industry are represented.

Seed and table-stock growers who are interested in growing certain cultivars should make their wishes known to their representatives on the committee or to the Provincial Potato Extension Specialist, who is the co-ordinator of the program, so that the build-up of stocks can begin as soon as possible.

Progressive producers of seed potatoes should apply to the nearest office of the Agriculture Canada Seed Potato Certification service for complete regulations and application forms. It is most important to pursue this well ahead of planting time.

Offices are located at the following places:

Toronto	- 4900 Yonge Street Suite 1210 Willowdale, Ontario M2N 6G7	(416) 224-3692
Barrie	- 370 Dunlop Street Barrie, Ontario L4N 5R7	(705) 728-8639

continued

London	- Box 577, Station B, N6A 4W8	(519) 679-4021
Ottawa	- 1301 Base Line Road, Meriline Court K2C 3S5	(613) 998-9926
Winnipeg, Manitoba	- 730-269 Main Street R3C 1B2	(204) 949-3775

SELECTED ONTARIO MINISTRY OF AGRICULTURE AND FOOD
PUBLICATIONS CONTAINING INFORMATION ON POTATOES

No. 74, *Guide to Chemical Weed Control*

No. 363, *Vegetable Production Recommendations*

Factsheets:	Order Number
<i>Potatoes as a Livestock Feed</i>	72-145
<i>Potato Varieties</i>	78-085
<i>Ring Rot of Potato</i>	74-029
<i>Dry Rots of Potatoes in Storage</i>	75-059
<i>Reducing Mechanical Injury in Potato Handling</i>	70-049
<i>Black Scurf and Silver Scurf of Potatoes</i>	76-011
<i>Potato Quality</i>	75-012
<i>Cultural Practices for Potatoes</i>	76-050
<i>Blackleg of Potatoes</i>	79-038
<i>Late Blight of Potatoes</i>	79-043
<i>Black Heart and Jelly End Rot of Potatoes</i>	79-048

Unless stated otherwise, all bulletins referred to in this publication are published by the Ontario Ministry of Agriculture and Food.

CONVERSION TABLES

METRIC TO IMPERIAL

Length

1 millimetre (mm)	≈ 0.04 inch
1 centimetre (cm)	≈ 0.40 inch
1 metre (m)	≈ 39.40 inches
1 metre (m)	≈ 3.28 feet
1 metre (m)	≈ 1.09 yards
1 kilometre	≈ 0.62 mile

Area

1 square centimetre (cm ²)	≈ 0.16 square inch
1 square metre (m ²)	≈ 10.77 square feet
1 square metre (m ²)	≈ 1.20 square yards
1 square kilometre (km ²)	≈ 0.39 square mile
1 hectare (ha)	≈ 107.636 square feet
1 hectare (ha)	≈ 2.5 acres

Volume (liquid)

1 millilitre (mL)	≈ 0.035 fluid ounce
1 litre (L)	≈ 1.76 pints
1 litre (L)	≈ 0.88 quart
1 litre (L)	≈ 0.22 gallon (Imperial)
1 litre (L)	≈ 0.26 gallon (U.S.)

Volume (dry)

1 cubic centimetre (cm ³)	≈ 0.061 cubic inch
1 cubic metre (m ³)	≈ 1.31 cubic yards
1 cubic metre (m ³)	≈ 35.31 cubic feet
1000 cubic metres (m ³)	≈ 0.81 acre-foot
1 hectolitre (hL)	≈ 2.8 bushels

Weight

1 gram (g)	≈ 0.035 ounce
1 kilogram (kg)	≈ 2.21 pounds
1 tonne (t)	≈ 1.10 short tons
1 tonne (t)	≈ 2205 pounds

Speed

1 metre per second	≈ 3.28 feet per second
1 metre per second	≈ 2.24 miles per hour
1 kilometre per hour	≈ 0.62 mile per hour

Pressure

1 kilopascal (kPa)	≈ 0.15 pounds/square inch
--------------------	---------------------------

Temperature

°F = (°C × 9/5) + 32
°C = (°F - 32) × 5/9

Proportion

1 litre per hectare	≈ 14.24 fluid ounces per acre
1 kilogram per hectare	≈ 14.50 ounces avdp per acre
1 kilogram per square centimetre	≈ 14.23 pounds per square inch
1 hectolitre per hectare	≈ 1.10 bushels per acre

IMPERIAL TO METRIC

Length

inch	≈ 2.54 cm
foot	≈ 0.30 m
yard	≈ 0.91 m
mile	≈ 1.61 km

Volume (dry)

cubic yard	≈ 0.76 m ³
bushel	≈ 36.37 L

Area

square foot	≈ 0.09 m ²
square yard	≈ 0.84 m ²
acre	≈ 0.40 ha

Volume (liquid)

fluid ounce (Imp.)	≈ 28.41 mL
pint (Imp.)	≈ 0.57 L
gallon (Imp.)	≈ 4.55 L
gallon (U.S.)	≈ 3.79 L

Weight

ounce	≈ 28.35 g
pound	≈ 453.6 g
ton	≈ 0.91 tonne

Pressure

pound per square inch	≈ 6.90 kPa
-----------------------	------------